Some Guidelines for Helping Natural Resources Adapt to Climate Change

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Flexibility in management approaches will be critical to maintaining ecological resilience in mountains and other ecosystems in a changing climate

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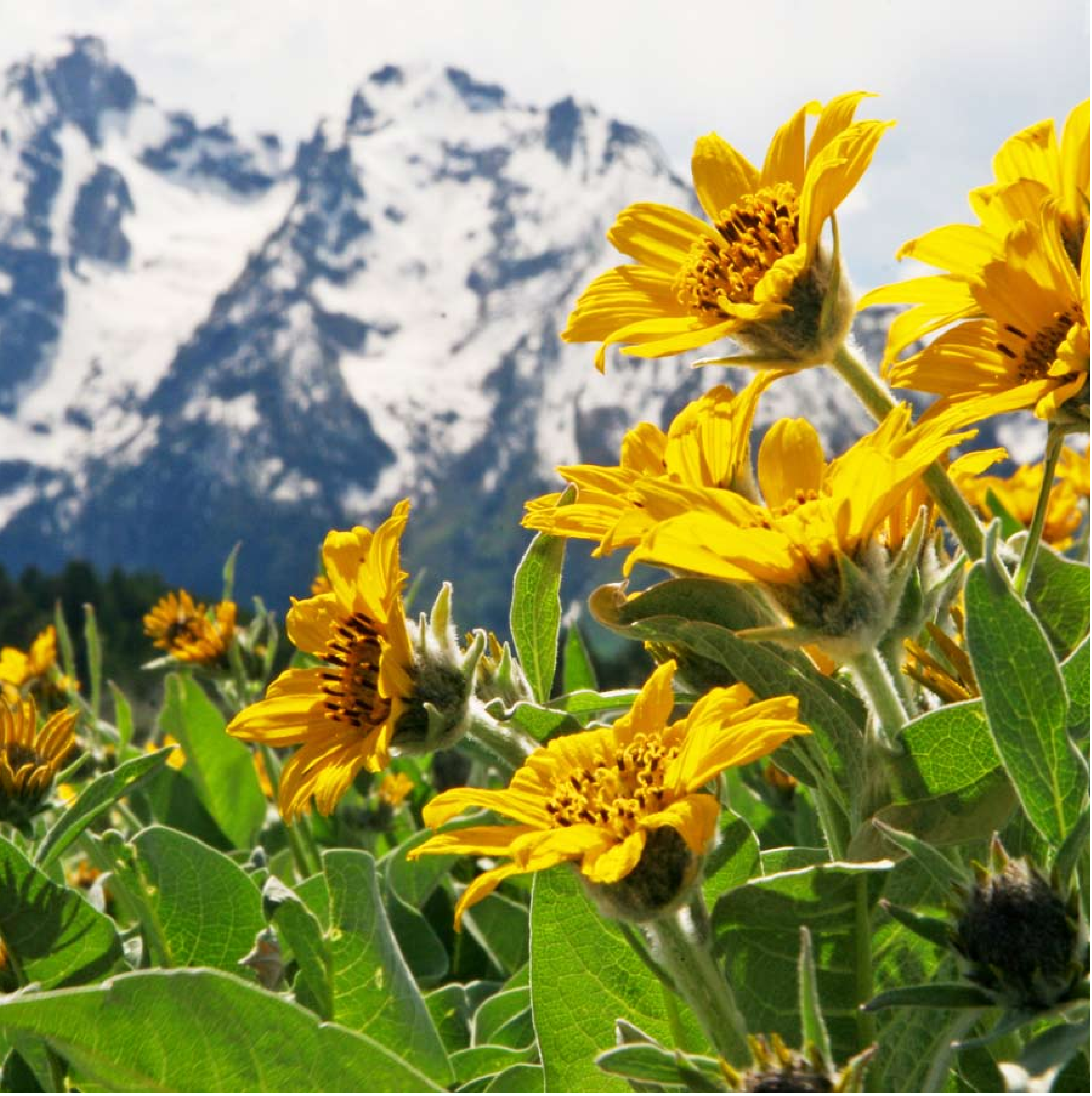
The changes occurring in mountain regions are an epitome of climate change. The dramatic shrinkage of major glaciers over the past century – and especially in the last 30 years – is one of several iconic images that have come to symbolize climate change.

Climate creates the context for ecosystems, and climate variables strongly influence the structure, composition, and processes that characterize distinct ecosystems. Climate change, therefore, is having direct and indirect effects on species attributes, ecological interactions, and ecosystem processes. Because changes in the climate system will continue regardless of emissions mitigation, management strategies to enhance the resilience of ecosystems will become increasingly important. It is essential that management responses to climate change proceed using the best available science despite uncertainties associated with the future path of climate change, the response of ecosystems to climate effects, and the effects of management. Given these uncertainties, management adaptation will require flexibility to reflect our growing understanding of climate change impacts and management effectiveness[1].

A recently released report by the US Climate Change Science Program: Preliminary Review of Adaptation Options for Climate-Sensitive Ecosystems and Resources identifies adaptation strategies for US national forests, national parks, wildlife refuges, wild and scenic rivers, estuaries and marine sanctuaries[2]. Fully one third of the world's legally protected areas, including many US national parks and forests, are in mountains[3]. Elevation and climatic gradients make mountains especially vulnerable to climate change, thus management approaches that encourage natural processes and populations to adapt to changing climates will become increasingly important.

Starting with the management goals of each of these systems, scientists identified approaches that could increase



the short-term resilience (over perhaps the next several decades) of ecosystems, resilience being defined as the amount of change or disturbance an ecosystem can absorb before it enters a fundamentally different state. As climate continues to change, however, resilience thresholds will likely be exceeded. Thus, longer-term adaptation approaches will require flexibility, managing for changing conditions instead of fixed goals, and management approaches that acknowledge uncertainty (TABLE 1). Case studies, although certainly not definitive, were used to begin to apply principles of adaptation to specific US public lands (BOX AND MAP).

Successful adaptation of natural resource management to climate change begins by identifying resources and processes at risk from climate change, defining thresholds and reference conditions, establishing monitoring and assessment programs, and engaging in management actions that increase the resilience of these resources. Adaptation strategies include scenario planning; adaptive management, including an increased capacity to learn rapidly from man-

Case study summary

The authors of Synthesis and Assessment Products: Adaptation Options for Climate-Sensitive Ecosystems and Resources (SAP) 4.4 explored opportunities to adapt to climate change in 13 case studies encompassing the range of ecosystems and types of federally managed systems covered in the report (see map). In general, these ecosystems will face warmer temperatures, more frequent and prolonged droughts, and more precipitation falling in intense storms. Moreover, many of the cases examined will face limits in water availability due to a combination of decreased snowpack, earlier spring snowmelt, and increased evaporation and runoff. Mountain ecosystems will likely suffer more severe insect and disease outbreaks, longer fire seasons and more severe fires, and shifts in biotic communities (e.g., cold-water dependent fishes) due to warmer air and water temperatures.

Although the specific adaptation options varied by management context, some common themes emerged from across the case studies. For example, many case studies emphasized the need to capitalize on the flexibility in current planning processes and to explicitly incorporate climate change considerations in management plans. Another key theme was the importance of implementing better monitoring systems to provide salient information for improved decisions for climate change adaptations. Similarly, most of the case studies emphasized the need for education (of management staff and the public) about the science of climate change and its implications. Engaging landowners to manage vegetation near buildings and dwellings, for example, would help the US Forest Service minimize risks to property and lives from the expected increase in wildfires within the landscape mosaic of National Forests. Finally, several case studies highlighted the need for a strong science-management partnership to develop and implement adaptations. The Olympic National Forest case study, for example, noted that collaboration with other agencies and organizations helped develop innovative climate change adaptations for the benefit of many stakeholders.

agement successes and failures; and examining and responding to the multiple scales at which species and processes function. The latter most certainly will require regional to international partnerships and a shared vision among multiple organizations. Science-based management principles will become more critical because past experience may not serve as a guide for novel future conditions. Preparing for and adapting to climate change is as much a cultural and intellectual challenge as an ecological challenge[4].

Table 1
Steps to implementing adaptations to climate change for park and reserve managers

1. Identify resources and processes at risk from climate change
2. Establish reference conditions, identify thresholds, and monitor for change
3. Assess, plan, and manage at multiple scales, letting the issues define the appropriate scales of time and space
4. Form partnerships with other resource management entities
5. Increase reliance on adaptive management and scenario-based planning
6. Use best management practices to reduce other human-caused stresses to park and reserve ecosystems
7. Reward managers who adopt approaches that increase understanding and accelerate the pace of learning

Identifying resources and processes at risk from climate change

Systematic characterization of potential climate changes on resources can be accomplished through summaries of the literature, guided research, gatherings of experts, and workshops where scientists, managers, and the public discuss risks to resources. We caution against the tendency to insist on high-resolution climate forecasts before undertaking this exercise. While detailed and site-specific climate forecasts may be helpful for specific applications, general projections may be sufficient for the initial stages of risk assessment. Subsequent iterations of the exercise can explore resource risk in more detail. It may be useful to rank susceptibility of resources and processes based on the speed of expected response, the role that species or processes play in the ecosystem, the importance of the species or resources to meeting management goals, and the ecological and socioeconomic potential for adaptation. Assessment of risk requires explicit consideration of how crossing thresholds will affect valued species, communities, ecosystem processes, and their interactions. Climate change provides the impetus to identify not only acceptable versus unacceptable change, but controllable versus uncontrollable change.

Establishing reference conditions, identifying thresholds, and monitoring for change.

Climate changes may cause ecological thresholds to be exceeded, leading to abrupt shifts in the structure of ecosystems. Threshold changes in ecosystems have profound implications for management because such changes may be unexpected, large, and difficult to reverse. Understanding where thresholds have been exceeded in the past and where (and how likely) they may be exceeded in the future allows managers to plan accordingly and avoid tipping points where possible. Activities taken to prevent threshold changes include establishing reference conditions, modeling a range of possible climate changes and system responses, monitoring to identify relevant ecological changes, and responding by implementing adaptation actions at appropriate scales and times.

Reference conditions determined partly by observations and data from the past, including paleoenvironmental records, help managers and scientists identify ecological states or regimes, and hence guide management activities. But reference conditions are also value statements; what a set of individuals identify as important. With uncertain future climates, managing to return to a reference condition may no longer be the appropriate goal[5]. Knowledge of the ecological and physical setting that produced the reference condition is still useful, however. If the reference condition would incur greater resilience to human-caused disturbance, including climate change, than current conditions, it provides a goal for protection or restoration. Alternatively, if the reference condition is highly dependent on past climate conditions, it identifies the need for adaptation to new conditions. Scientific evidence that past and highly valued conditions are no longer attainable may provide the incentive to plan for ecosystems that are sustainable under future conditions[6].

Table 2
Some Adaptation Approaches for Climate Sensitive Ecosystems

1. **Reduce anthropogenic stresses**: minimize localized human-caused disturbances (e.g., pollution, fragmentation) that hinder the ability of species or ecosystems to withstand climatic events.
2. **Protect key ecosystem features**: manage to maintain structural characteristics, organisms, or areas that support the overall system.
3. **Maintain representation**: protect variant forms of a species or ecosystem so that, as climate changes, there may be populations that survive and provide a source for recovery.
4. **Replicate**: maintain or establish more than one example of each ecosystem or population within a management system, such that if one area is affected by a disturbance, replicates in another area may reduce risk of extinction and provide a source for recolonization.
5. **Restore**: rehabilitate ecosystems that have been lost or compromised.
6. **Identify refugia**: use areas that are less affected by climate change than other areas as sources for recovery or as destinations for climate-sensitive migrants.
7. **Relocate**: transplant organisms from one location to another in order to bypass a barrier (e.g., urban area).

Managing at multiple scales:

Complex ecological systems operate and change at multiple spatial and temporal scales. The scales at which ecological processes operate often will dictate the appropriate scales at which management institutions should be developed. Migratory bird management, for instance, requires international collaboration; ungulates and carnivores with large home ranges call for regional collaboration; marine preserves require cooperation among many stakeholders; all are examples where managers cannot be effective working solely within park or reserve boundaries. Similarly, preparation for rapid events such as floods will be managed quite differently than responses to climate impacts that occur over decades. Species may be able to move to favorable climates and habitats over time if there is appropriate and connected habitat.

Increasing reliance on adaptive management and scenario planning.

Ecosystems that provide societal goods and services are complex systems within a complex landscape. Doak and others[7] suggest complexity and surprises reinforce the need for management plans that are highly precautionary, rather than plans that assume specific management actions will have specific outcomes. The two major factors that influence selection of strategies for managing complex systems are the degree (and type) of uncertainty and the extent to which key ecological processes can be controlled. Most current approaches toward resource management are appropriate when uncertainty is low and specific activities are likely to achieve a clear outcome. But the changes to ecosystems that will result from interactions of natural dynamics, anthropogenic change, and novel climates will increasingly negate the ability to manage for specific outcomes. Adaptive management, which is a process that integrates learning with management actions, is applicable to circumstances where there is ability to influence an ecological process, but uncertainty as to the best methods [8,9,10]. By treating management activities as hypotheses, adjustments are made in decisions as outcomes from management actions and other events are better understood. This method supports managers in taking action today using the best available information while also providing the possibility of ongoing future refinements through an iterative learning process. Scenario-based planning provides a way of envisioning a range of quantitative or qualitative plausible futures[11]. Adaptation responses can then be developed for the range of plausible futures; this approach is more robust to uncertainties than managing for any single projection of the future.

Adaptation Approaches

The report identified seven resource management approaches that might confer short-term resilience to ecosystems and highly valued species (TABLE 2). Protecting key ecosystem features involves focusing management protections on structural characteristics, organisms, or areas that represent important “underpinnings” or “keystones” of the overall system. Reducing anthropogenic stresses is the approach of minimizing localized human stressors (e.g., pollution, fragmentation) that hinder the ability of species or ecosystems to withstand climatic events. Maintaining representation refers to protecting a portfolio of variant forms of a species or ecosystem so that, regardless of the climatic changes that occur, there will be areas that survive and provide a source for recovery. Replicating centers on maintaining more than one example of each ecosystem or population such that if one area is affected by a disturbance, replicates in another area provide insurance against extinction and a source for recolonization of affected areas. Restoring is the practice of rehabilitating ecosystems that have been lost or compromised. Identifying refugia refers to taking advantage of areas that are less affected by climate change than other areas and as sources of "seed" for recovery or as destinations for climate-sensitive migrants. Relocating refers to human-facilitated transplantation of organisms from one location to another in order to bypass a barrier (e.g., urban area)[1,2].

We estimated confidence in the ability of each of the seven approaches to provide resilience by quantifying the amount of available evidence to support the determination that the effectiveness of a given adaptation approach is well-studied, understood, and agreed upon throughout the scientific community. The resulting confidence estimates varied both across approaches and across management systems. Reducing anthropogenic stresses was the one approach for which there was considerable scientific confidence in its ability to promote resilience for virtually any situation. Confidence in the other approaches—including protecting key ecosystem features, representation, replication, restoration, identifying refuges, and especially relocation—was much more variable.

Many existing management practices can be applied to protect ecosystems from some aspects of climate change. Changes in temperature, precipitation, sea level, storm intensity and other climate-related factors can exacerbate problems that are already of concern to managers. Fortunately, many existing management practices also can address these climate change interactions. For example, reducing the delivery of pollutants to estuaries may enhance physiological resistance of many estuarine species to elevated water temperature. Another existing approach, use of riparian buffer strips, is effective at limiting nutrient and sediment loadings from agricultural lands into rivers under a wide range of current climates, suggesting that it will be effective under future climates as well. However, this does not mean that managers should only continue or intensify existing practices; they also need to explore key adjustments in the timing, spatial extent, and location of their practices to ensure greatest effectiveness given climate change.

Photo: Buffalo at Yellowstone National Park, USA; copyright Matt Hintsa

The importance of communication, trust, and scientist-manager-public partnerships

Even highly reasoned actions have some potential to go awry, especially as climate changes. Although clearly not desired, failures provide opportunities for learning. Continued and expanded public education about the complexity of resource management, transparency in the decision-making process, frequent public updates on progress or setbacks, and internal agency efforts that promote trust and respect for professionals within the agency are all important methods for promoting more nuanced management efforts. Partnerships among managers, scientists, educators, and the public can go a long way toward efficiently closing information gaps. With good communication and coordination, scientists can target their research to better inform management challenges, resource managers can share data and better design monitoring to test scientific hypotheses, and outreach specialists can better engage the public in understanding and supporting adaptation activities.

Managing for change

Adapting to climate change may require more than simply changing management practices—it could require changing management goals. In other words, when climate change has such strong impacts that original management goals are untenable, the prudent course may be to alter the goals. At such a point, it will be necessary to manage for and embrace change. Climate change requires new patterns of thinking and greater agility in management planning and activities in order to respond to the inherent uncertainty of the challenge. There are no clear answers yet for how exactly to proceed, but a critical dialog among engaged stakeholders including scientists, managers, and the public may help chart the way forward.

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